Remarks/Arguments:

The rejection under 35 USC 103 over Kaplan in view of Kalina is respectfully traversed.

It must be reiterated that Claims 10-15 are method claims. The mere presence of similar, or even identical, components in a method does not make the methods equivalent. A key process step in the method of the present application is the use of recuperator **31** (in Figure 4/8 *inter alia*)to preheat and <u>partially vaporize</u> the working fluid. This means that the heater (e.g. **33** in Figure 4/8) is not acting as a boiler, converting a working fluid in substantially liquid form to vapor. Heating and partially vaporizing the working fluid results in inherently safer operation of heater **33** since it is heating a compressible vapor rather than an incompressible liquid.

Kaplan contains no such process step, and the recuperator of Kaplan serves to cool (by removal of sensible heat) the depleted vapor exiting the turbine. This is clearly shown, for example, in Claim 1 paragraph f) of Kaplan, "... and a recuperator for receiving said organic fluid condensate from said condenser, and for receiving said organic vapor that exits from said turbine thereby <u>transferring heat from the vapor that exits the turbine to said organic fluid condensate before said organic fluid condensate reaches said preheater</u>." [Emphasis added]. And further, in Claim 2 of Kaplan, paragraphs e) and h):
"e) a recuperator responsive to said organic vapor that exits from the turbine for heating organic fluid and producing cooled heat depleted organic vapor;
h) said preheater and said recuperator being constructed and arranged so that <u>substantially all of the organic fluid condensate pumped into said vaporizer is in a liquid state</u> at said vaporization temperature when such fluid enters the vaporizer" [Emphasis added.]

There would be no benefit, or motivation, in the process of Kaplan, of using a multicomponent ammonia-water working fluid. The characteristic and advantage of such a two-component non-azeotrope forming working fluid is that it vaporizes (and condenses) over a temperature range, and hence absorbs (or transfers) latent heat over a temperature range. As Kaplan claims (Claim 1, paragraph b)): "b) a vaporizer containing an organic fluid and responsive to said geothermal steam for [C4L34] <u>vaporizing said organic fluid at constant temperature and pressure</u> thereby producing vaporized organic fluid and geothermal steam condensate;" {Emphasis added.]

There appears to be no new teaching by Kaplan concerning the organic Rankine cycle itself. By adding his brine pre-heater, Kaplan has not changed the organic Rankine cycle in any functional way. If Kaplan has shown no motivation concerning the organic Rankine cycle, then he clearly has no motivation to modify it.

In stating that "Kaplan teaches all basis (sic) elements of the invention with the exception of using different working fluid", the Examiner appears to be equating "elements"

with "equipment". Kaplan clearly does not teach the basic elements of the present invention with respect to operations, conditions and implications. The functions of each heat exchanger used by Kaplan would need to be materially changed by the introduction of a multi-component fluid. Moreover, the flow path of the working fluid would be changed in the embodiment using a preheater. The Kaplan recuperator would no longer be a vapor-to-liquid exchanger that suggests a finned tube design. The Kaplan condenser would no longer be a constant temperature unit which requires a different heat transfer analysis to determine sizing. The Kaplan vaporizer would no longer be a "boiler" with its inherent operational dangers. The Kaplan preheater has no comparable function to any equipment in the Smith disclosure. The organic Rankine cycle of the Kaplan disclosure can be adjusted to accommodate the change from one single-component fluid to another single-component fluid (e.g. pentane to butane) but it is not amenable to a change to a multi-component fluid.

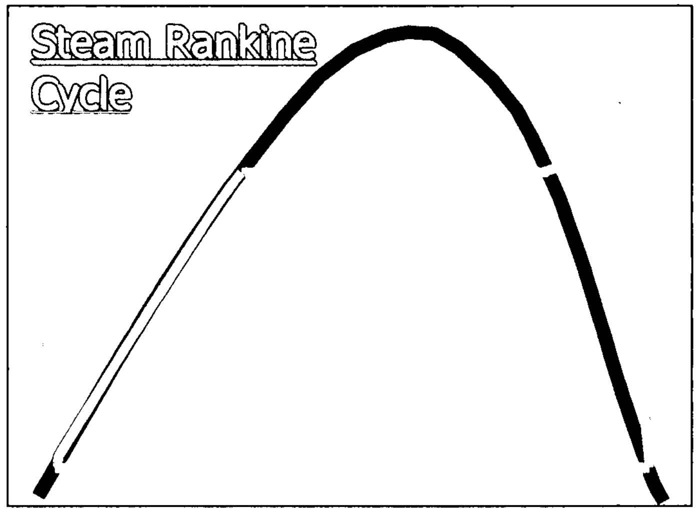
Kaplan describes the operation of the recuperator and, in so doing, makes it clear that his understanding is based on the properties of organic fluids, properties which are not applicable to a multi-component mixture of ammonia-water [Kaplan column 3 lines 15-28]. Kaplan recognizes that only vapor superheat energy is available for recuperation [Kaplan column 3 lines 27-28] and that this recuperation capability is due to the shape of the T-S diagram being tilted to the right [Kaplan column 3 lines 17-23]. In contrast the ammonia-water working fluid properties have a largely symmetrical shape of its T-S diagram [Smith Fig. 6] which negates the Kaplan technique of recuperation. The recuperation energy of ammonia-water working fluid comes largely from latent heat due to partial condensing which is not possible with the Kaplan system. The accompanying diagram on page 4 herein clearly illustrates the significant thermodynamic features of the Steam Rankine cycle, the organic Rankine cycle, and the power cycle of the present invention.

It is well-known that when the T-S diagram is tilted to the right, as in organic fluids, there is no need to superheat the fluid and there is always superheat available in the turbine exhaust. When the T-S diagram is symmetrical, it is ideal to superheat just enough that the turbine exhaust is saturated and even beginning to condense.

Kaplan clearly identifies "organic fluids suitable for use in Rankine cycle power plants {e.g., pentane, and isopentane)" [Kaplan column 3 lines 19-20]. He does not indicate or suggest other alternative working fluids nor does he indicate any motivation to consider alternative working fluids. In particular, Kaplan shows no motivation to consider other fluid properties or how other fluid properties could alter the Rankine cycle operation to be different than what he teaches.

Power Cycle Comparisons

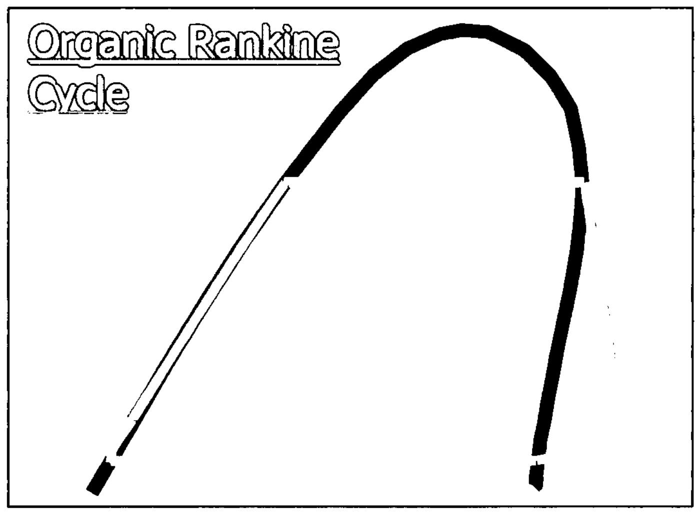
The figures shown are T-S diagrams (temperature vs entropy) for various Rankine cycles. It gives a quick visual reference of the differences between them. These diagrams indicate fluid operating characteristics but not power levels.



Black lines on each diagram indicate the saturation dome of the working fluid. Left of the dome is liquid and right of the dome is vapor. Within the dome the fluid is a two-phase vapor/liquid mixture.

Dark Blue and Red lines indicate heat input into the cycle.

Light Blue lines indicate heat output from the cycle.

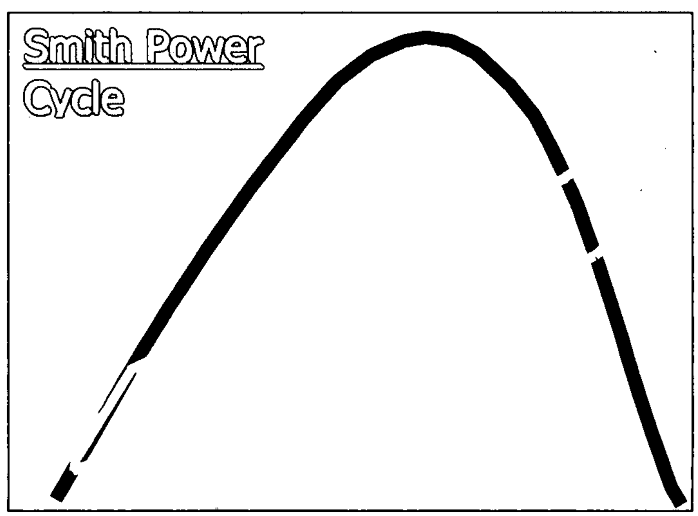


Purple lines indicate energy extraction by expansion through a turbine impeller.

Green lines indicate energy that is recuperated within the cycle. Energy in the green line on the right side of the diagram is transferred to the green line on the left side.

Steam Rankine Cycle
There is no inherent availability for energy recuperation within this cycle.

Organic Rankine Cycle
No superheat of the working fluid is required due to the shape of the saturation dome. Only sensible energy in the turbine exhaust vapor is available for recuperation into the high pressure liquid



Smith Power Cycle
Both sensible and latent heat in the turbine exhaust fluid can be recuperated into the high pressure liquid. Pre-vaporization of working fluid changes the heater characteristics. The cooler operates at a higher upper temperature requiring less coolant and yielding useful energy. Large quantities of energy can be recuperated within the cycle.

Conventional thermodynamic textbooks, for instance "Applications of Thermodynamics" by Bernard D. Wood 1969 Addison-Wesley Publishing Company Inc. pages 28-31(copies appended as Attachment 1), describe all of Kaplan's teaching concerning the use of an organic working fluid, using fluids with the property of "the T-S diagram being tilted to the right", identifying the superheat sensible energy as available for regeneration and even naming the regeneration technique as "feed heating". This textbook describes the many variations of the Rankine cycle with respect to working fluids, reheat techniques and recuperation methods but does not recognize the application of a multi-component working fluid. There is nothing in Kaplan's disclosure that indicates greater awareness of, or motivation for, using a multi-component working fluid than disclosed by Bernard Wood in his 38 year old textbook. The single inventive feature of Kaplan is the slight additional recovery of energy from geothermal brine using preheater 22.

The operation of the organic Rankine cycle taught by Kaplan differs from the operation of the multi-component fluid power cycle taught in the present application. Recuperator 32, condenser 35, preheater 22, and vaporizer 19 of Kaplan each operates differently than recuperator 31, cooler 36, preheater 32 and heater 33 taught in the present application. These differences are material to the particular benefits obtained from the present invention, not obtained by Kaplan, and therefore cannot be obvious to Kaplan.

Recuperator 32 of Kaplan can recover only sensible heat from the vapor superheat of the working fluid [Kaplan column 3 lines 26-27] as well as supply only sensible heat to the high pressure working fluid liquid [Kaplan column 3 lines 5-8] and this is a major influence on the equipment design. Recuperator 31 of the present invention can recover approximately 50% of the latent heat of the working fluid vapor [Smith lines 138-140, Fig. 6, lines 395-411] while pre-vaporizing over 2/3 of the high pressure working fluid liquid [Smith lines 135-138, Fig 6, lines 395-411] and this has a significant, and very different, influence on the equipment design.

Kaplan only refers to condenser 35 as a generic condenser [Kaplan column 3 lines 34-38] which is known by persons skilled in the art to operate at a substantially constant temperature and pressure of the working fluid. Coolant used by Kaplan cannot exceed temperature 36 at the outlet of the condenser 35. In contrast, cooler 36 of the present invention operates with a changing working fluid temperature [Smith lines 92-95, lines 150-152, Fig 6, lines 395-411] and coolant 18 can be heated above the boiling temperature of the working fluid [Smith lines 93-95]. This gives an advantage to Smith of reduced coolant flow, reduced pumping, increased and more useful temperature as well as smaller equipment.

Preheater 22 of Kaplan operates completely different and for a different reason than preheater 32 of present application. Kaplan uses preheater 22 to increase the energy input into the working fluid, uses geothermal brine as the energy source and adds only sensible heat to the liquid working fluid [Kaplan column 3 lines 5-8]. Preheater 32 of the present invention does not

introduce additional energy into the working fluid but redistributes energy within the working fluid to complete vaporization of the working fluid before it enters heater 33 [Smith lines 156-169]. Preheater 32 of the present invention uses working fluid on both sides of the exchanger and does not accept an outside fluid such as brine used by Kaplan. Preheater 32 of the present invention vaporizes working fluid before being fed to heater 33 while preheater 22 of Kaplan only provides sensible heating of its organic working fluid before being fed to vaporizer 19.

Furthermore, vaporizer 19 of Kaplan accepts only liquid working fluid and fully vaporizes it. This is the same function as a boiler and vaporizer 19 carries the same inherent dangers as boilers. A confined liquid fluid that is heated, as in a boiler, will show an explosive rise in pressure. Such equipment requires highly trained and registered operators to ensure safety. In contrast, heater 33 of Smith accepts a pre-vaporized working fluid. Even a 50% pre-vaporization of incoming working fluid means that confined fluid that is heated will show a controllable rise in pressure. It is similar to an air heater in operation [Smith lines 318-327]. This is an inherent safety in the process disclosed in the present application, and a principle advantage of that process, and it is absent from and not recognized in the Kaplan disclosure.

Thus the process taught by Kaplan is markedly different from the process taught and claimed in the present application, and the apparatus claimed by Kaplan, while similarly named, is markedly different in operation. Kaplan discloses no consideration of an ammonia-water working fluid, and as the analysis above indicates, the use of such a working fluid would require complete re-engineering of the Kaplan apparatus; in effect an invention in hindsight of the invention of the present application.

In fact, in claiming (Claim 1, paragraph b) "a vaporizer containing an organic fluid and responsive to said geothermal steam for [C4L34] <u>vaporizing said organic fluid at constant temperature and pressure</u> thereby producing vaporized organic fluid and geothermal steam condensate" [Emphasis added], Kaplan clearly does not show any recognition of the advantage of a two-component non-azeotrope forming working fluid, which vaporizes over a range of temperature. Thus Kaplan contains no teaching which would suggest any advantage to be gained by using the ammonia-water working fluid of the present invention, and, in fact, teaches away from such use. Therefore, the rejection under 35 USC 103 over Kaplan in view of Kalina is respectfully traversed.

The rejection under 35 USC 103 over Maisotsenko *et al* in view of Kalina (U.S. Patent 4,548,043) is also respectively traversed. Examiner states (page 4, last sentence) "It would have been obvious...to improve efficiency." Maximum efficiency is not a principle objective of the Smith process. The process was developed primarily for use in the forest products industry, where combustible waste useable as fuel is plentiful; it was developed to keep capital costs, and especially operating costs, low, and not primarily to optimize efficiency. To this end, the process uses ammonia-water as the working fluid, and uses a recuperator heat exchanger to preheat and

partially vaporize the working fluid before feeding it into the primary heater **33**. This renders the primary heater inherently safer, and capable of operating safely with less highly trained unlicensed operators.

Applicant also believes that Examiner's statement (p2, last paragraph)"Maisotsenko *et al* already teaches that his invention can be used in a Kalina cycle..." is incorrect. Maisotsenko *et al* suggest that <u>a component</u> developed for their system could be used in a Kalina cycle, (at C21L33-36) "The <u>evaporative duplex counterheat exchangers</u> may be used in other power systems for producing power and reaching high thermal efficiencies, such as systems based on the Rankine cycle, Kalina cycle,...". (Emphasis added.) However, there is no teaching as to how that might be done, or the changes that would be necessitated or result from such change, nor how their evaporative duplex counterheat exchangers could enhance operation. Also, it should be noted that the "Kalina cycle", as disclosed and claimed in the several U.S. patents issued to Kalina, depends on the separation of the ammonia-water working fluid into separate ammonia-rich and water-rich streams, each of which stream is subsequently used differently. The present invention uses on a single working fluid throughout, with no separation into substreams.

Maisotsenko *et al* do state that their motivation is to apply their duplex counterheat exchangers "wherever condensing process is used in power generation" [Maisotsenko column 21 line 37]. Maisotsenko et al do not indicate any interest or motivation in combining features of various power cycles to produce a different power cycle. There is simply no basis to suggest that such an action would be "obvious" to Maisotsenko et al.

Examiner also points out (in the same paragraph) "the only missing element is the counter flow recuperator which is well known in the art as taught by Kalina to control the temperature of the working fluid". The recuperator, which is not used in the process of the present application to control the temperature of the working fluid but to heat and partially vaporize the working fluid. It is called by the same name, but its function or operation in the process is quite different. (See discussion above). For this reason, applicant respectfully traverses the rejection under 35 USC 103 over Maisotsenko *et al* in view of Kalina.

The invention and claim of Maisotsenko *et al* is a technique of using air (or other vapor) as a coolant and reducing its sensible temperature to approach its due point temperature by evaporative cooling within the cooling air itself and kept separate from the working fluid being cooled. The assertion of Maisotsenko *et al* is that this temperature is lower and simpler than other cooling techniques. Their teaching is an application of their "evaporative duplex counterheat exchanger" to existing power cycles in various places where teaching <u>by others</u> has already identified opportunities for cycle enhancement. There is no teaching of, or motivation for, new power cycles by Maisotsenko *et al.*

Examiner's comment (bridging pps 2 & 3) that "Therefore, it would have been obvious to

use the recuperator in Maisotsenko et al with the counter-flow heat exchanger as taught by Kalina to get the desired temperature." is respectfully traversed. Maisotsenko et al teach an application of their duplex counterheat exchangers to the steam Rankine cycle [Maisotsenko column 21 line 56 – Column 22 line25]. There are two aspects described in this teaching of Maisotsenko et al. The first (1) is a reduced temperature for the coolant used in condenser 202 and the second (2) is the recovery of reject heat to recuperator 201. Neither of these applications would be a meaningful enhancement of the power cycle that Smith teaches.

Firstly, the reduced temperature of the coolant entering condenser 202 requires that the coolant be air (or other vapor) and that this air be modified in humidity within their duplex counterheat exchanger. This approach of Maisotsenko *et al* assumes that energy from the cycle is being "rejected" and "wasted" by heat transfer within the condenser. The approach of Maisotsenko et al seeks to minimize the temperature of coolant 15 at all points in condenser 202 which reduces the usefulness of the coolant for unrelated, beneficial heating applications, such as is taught by the present application. Applying the duplex counterheat exchanger of Maisotsenko *et al* teaches away from the feature taught in the present application "...that higher outlet temperature 21 of said ammonia-water thermodynamic cycle may be used effectively for unrelated, beneficial heating applications..." [Smith lines 291-294].

There is nothing in the application of the duplex counterheat exchanger of Maisotsenko *et al* to the present invention that addresses a significant feature that Smith discloses, in particular, "It is an aspect of this invention that temperature 21 of said third fluid may be greater than temperature 1 of said working fluid by using a counter-flow heat exchanger as cooler 36" [Smith lines 93-95]. The Smith disclosure teaches a benefit of heating the coolant above the condenser outlet temperature of the working fluid. The duplex counterheat exchanger of Maisotsenko *et al* may or may not be capable of the same effect within the cycle Smith teaches, however there is nothing in the invention of Maisotsenko *et al* that would enhance that effect or even recognize it. Maisotsenko *et al* seek to minimize the temperature of the coolant in order to reduce the condensing temperature of the working fluid. A lower coolant temperature reduces its usefulness for unrelated, beneficial heating applications.

Furthermore, because the invention of Maisotsenko *et al* requires that the coolant be air (or other vapor) and using air requires larger equipment, it directly teaches away from another feature of the power cycle of the present invention, namely that "...that higher outlet temperature 21 of said ammonia-water thermodynamic cycle may be used effectively for unrelated, beneficial heating applications or cooled to cooler 36 inlet temperature of 18 <u>using smaller equipment</u> than would otherwise be necessary." [Smith lines 291-294]. The technique of Maisotsenko *et al* severely limits the ability to reduce the equipment size in that it limits the coolant to being a vapor.

Requiring the coolant to be air (or other vapor) also reduces the usefulness of the coolant

itself for unrelated beneficial heating applications. Air is a poor heat transport medium because it holds less heat, requires larger piping and pumping equipment and does not transfer its heat readily. It is implied in the examples of the present disclosure that the coolant effective for useful beneficial applications is liquid [Smith lines 382-411].

Secondly, the recovery of reject heat to recuperator 201 as taught by Maisotsenko *et al* appears to be impossible in the application they have described. Steam vapor leaving turbine 300, in any useful system, would be at the lowest possible pressure and temperature as determined by conditions of condenser 202. There should be little or no superheat in steam vapor 200 and the temperature of steam 200 and condensate 205 would be substantially the same. Sub-cooling condensate 205 within condenser 202 has no net energy transfer benefit to the cycle so should not be done. The temperature of coolant 15 must be less than the temperature of vapor 200 and condensate 205. Condensate 205 will increase in temperature slightly due to the energy input of pump 203. Therefore the temperature of coolant 15 entering recuperator 201 must be less than the temperature of condensate 205 entering recuperator 201. Heat will not transfer from coolant 15 (at a lower temperature) to condensate 205 (at a higher temperature) within recuperator 201 unless some unknown, unidentified external process is applied to one or other flow streams. The application described by Maisotsenko *et al* [Maisotsenko Fig. 11 and Column 22 Lines 5-25] would appear to be inoperative.

The recovery of reject heat to recuperator 201 as taught by Maisotsenko *et al* is not applicable to the power cycle disclosed in the present application. Using the arrangement in Fig. 11 of Maisotsenko *et al* with or without the direct recuperator disclosed in the teaching of the present application would result in no benefit for the Smith power cycle and, in fact, is expected to result in a net loss of efficiency. Recovered heat from condenser 202 of Maisotsenko *et al* that is transferred to fluid 205 in recuperator 201 would heat fluid 205, which would result in a reduction of energy transfer by direct recuperation as disclosed by Smith. The energy not recuperated in the Smith disclosure would then be transferred to coolant 15 in condenser 202 and a portion of it would be returned to fluid 205 in recuperator 201. There is no net benefit to the arrangement of Maisotsenko *et al* and it can be expected that there would be a net loss of efficiency in the power cycle disclosed in the present application. Since there is no benefit to applying Maisotsenko *et al* to the Smith power cycle and since there is no indication by Maisotsenko *et al* of awareness of the Smith power cycle, there can be no motivation for Maisotsenko *et al* to anticipate, or recognize as obvious, the invention taught and claimed in the present application.

Examiner's statement "Kalina teaches it's well known to use multi-component fluid using ammonia and water" is respectfully traversed. This statement is correct but only in so far as the multi-component fluid of ammonia and water is used in a version of the Kalina cycle. Neither Kalina nor the many other researchers studying the Kalina cycle have identified using the ammonia-water fluid for power production apart from the Kalina cycle. This can be noted in the

detailed post-graduate work of Maria Jonsson and of Eva Thorin both of which have been made of record in the examination of the present application. It is only "after the fact" that the process of the present application can be considered "obvious".

The Smith disclosure of using a multi-component working fluid in a direct Rankine cycle includes a large number of benefits and advances that are not available when using a single-component working fluid. Such benefits include recuperation of latent heat, pre-vaporized fluid entering the heater, inherent safety from leaks into flue gas, inherent safety of operation reducing operator qualification requirements, less coolant required, less coolant pumping energy required, higher outlet temperature of coolant, useful application for the reject heat, minimal loss of electrical conversion efficiency when biasing the system for combined heat and power application, and minimal loss of electrical conversion efficiency when making equipment simplification by single stage turbine operation. It is unreasonable to suggest that these benefits would be obvious to a person with ordinary skill in the art based on a change to a multi-component fluid in the processes disclosed by Kaplan or by Maisotsenko *et al*.. Without recognition of these benefits, there is no suggestion or motivation for such a person with ordinary skill in the art to make the required change to a multi-component fluid.

Examiner's comments "Claims 10-17 are rejected under 35 U.S.C. § 103(a) as being unpatentable over US 5664419 (Kaplan) in view of US 4548043 (Kalina)" (last paragraph on p 3 of the Office Action) and "Claims 10-17 are rejected under 35 U.S.C. § 103(a) as being unpatentable over US 7007453 (Maisotsenko *et al*) in view of US 4548043 (Kalina)" are respectfully traversed. Applicant believes that this blanket rejection of all claims without recognition of the specific features of each claim is unwarranted. It is clear that each claim has its own distinctiveness and inventive concept which is not reflected or suggested in the references cited by the Examiner.

Claim 10 identifies numerous features in a power cycle that are not taught or acknowledged by Kaplan, Kalina or Maisotsenko *et al*. These include:

- partial condensing of turbine exhaust vapor in a direct feed heating recuperator,
- partial vaporization of liquid working fluid exiting the feed pump,
- using the heater with partially pre-vaporized working fluid
- operating the cooler with partially pre-condensed working fluid

These features are new, inventive and result from an appreciation of benefits derived by using a multi-component fluid in a non-conventional way.

Applicant is expert in the field of Rankine cycles and power systems, and would have seen this knowledge disclosed publicly if it were an obvious adaptation of the Rankine cycle as the Examiner maintains. To the best of his knowledge, there has been no such disclosure.

Claim 11 expands on the benefits of claim 10 by separating the cooler into two stages. This separation is only advantageous because of the property of multi-component fluids used in a power cycle as claimed in claim 10. It is the temperature change during condensation of the multi-component fluid that makes the two stage cooler possible. There is nothing in the references cited by the Examiner that suggests recognition of, or motivation for, this feature.

Claim 12 expands on the benefits of claim 10 by introducing a preheater to fully vaporize the working fluid before it enters the heater. This adds additional inherent safety to the power cycle. This enhancement is only possible because of the property of multi-component fluids used in a power cycle as claimed in claim 10. This function could not be done with a conventional or an organic Rankine cycle. There is nothing in the references cited by the Examiner that suggests recognition of, or motivation for, this feature.

Claim 13 introduces an application (biomass combustion) that is currently untapped for practical reasons. There is no other cost-effective system capable of performing this function on a small scale. This is further evidence that the power cycle disclosed in these claims is new, inventive and not obvious. It hasn't been done before even though the biomass application potential has been recognized for at least several decades.

Claim 14 introduces another application (use of waste heat from industrial precesses) that also is currently untapped for practical reasons. There is no other cost-effective system capable of meeting this function on the typical small scale.

Claim 15 identifies the apparatus that would fulfill the method of Claim 10. The equipment noted is named by function (e.g. heater, recuperator, etc.) however their design is determined by the special nature of the functions they perform. Due to the properties of the fluid and the conditions of operation, the design of equipment differs significantly from similarly named equipment of other power cycles. Furthermore, Claim 15 is limited to apparatus performing the unique operations of the process of the present invention, e.g. a recuperator for <u>heating and partially vaporizing</u> said high-pressure working fluid leaving the feedpump using heat from cooling and partially condensing low-pressure working fluid leaving a turbine, such recuperator arranged in counter-flow; and connection means for conveying <u>the entirety of said partially vaporized high-pressure working fluid to a heater</u>; [Emphasis added.]

Claim 16 expands on and is limited by Claim 15 by introducing two separate coolers used in stages. The design of these coolers is specific to the conditions of the working fluid. The changing temperature of the multi-component working fluid within these coolers necessitates specific designs that differ from conventional steam or organic Rankine cycle systems. There is nothing in the references cited by the Examiner that suggests recognition of, or motivation for, this feature nor any equipment with equivalent design criteria.

Claim 17 expands on and is limited by Claim 15 by introducing a preheater to fully vaporize the working fluid before it enters the heater. This preheater has a function that is unique to this power cycle and therefore has a design that differs from similarly named equipment of other power cycles. There is nothing in the references cited by the Examiner that suggests recognition of, or motivation for, this feature nor any equipment with equivalent design criteria.

In summary, the process of the present invention, as described in the present application, differs in fundamental ways from the processes of or Kalina. As explained above, introducing the ammonia-water working fluid into either Kaplan or Maisotsenko *et al* processes would not be possible or advantageous without a complete re-engineering of those processes, in essence, reinventing the process of the present invention. There is no indication that either Kaplan or Maisotsenko *et al* recognized the advantages which would accrue from such invention, and no suggestion or motivation to do so. Applicant believes the argument hereinabove overcomes the rejection of Claims 10-17 under 35 USC 103, and believes the application is in condition for allowance.

Respectfully submitted August 14, 2007

Laurence C Bonar

Laurence C. Bonar, Registration No. 33,838

Attachment 1

**Excerpts from "Applications of Thermodynamics"
by Bernard D. Wood 1969
Addison-Wesley Publishing Company Inc.
pages 28-31**

The ideal thermal efficiency for the cycle of Fig. 1.18 would be

$$\eta_{th} = \frac{\dot{m}_f(h_f - h_i) + (\dot{m}_f - \dot{m}_i)(h_i - h_j) + (\dot{m}_f - \dot{m}_i - \dot{m}_j)(h_j - h_k)}{\dot{m}_f(h_f - h_d)}.$$

One or more **open heaters**, also called **direct contact heaters**, might be used for regeneration. In these, the condensing vapors and the feed water mix intimately at the same pressure so that heat transfer is much more effective. Also, an open heater can act as a **deaerator** when properly vented to allow the escape of previously dissolved and entrained gases. Oxygen and carbon dioxide in boiler water accelerate metal corrosion. The calculations for flow rates for an open heater are essentially the same as for a closed heater. All leaving fluids will be in equilibrium.

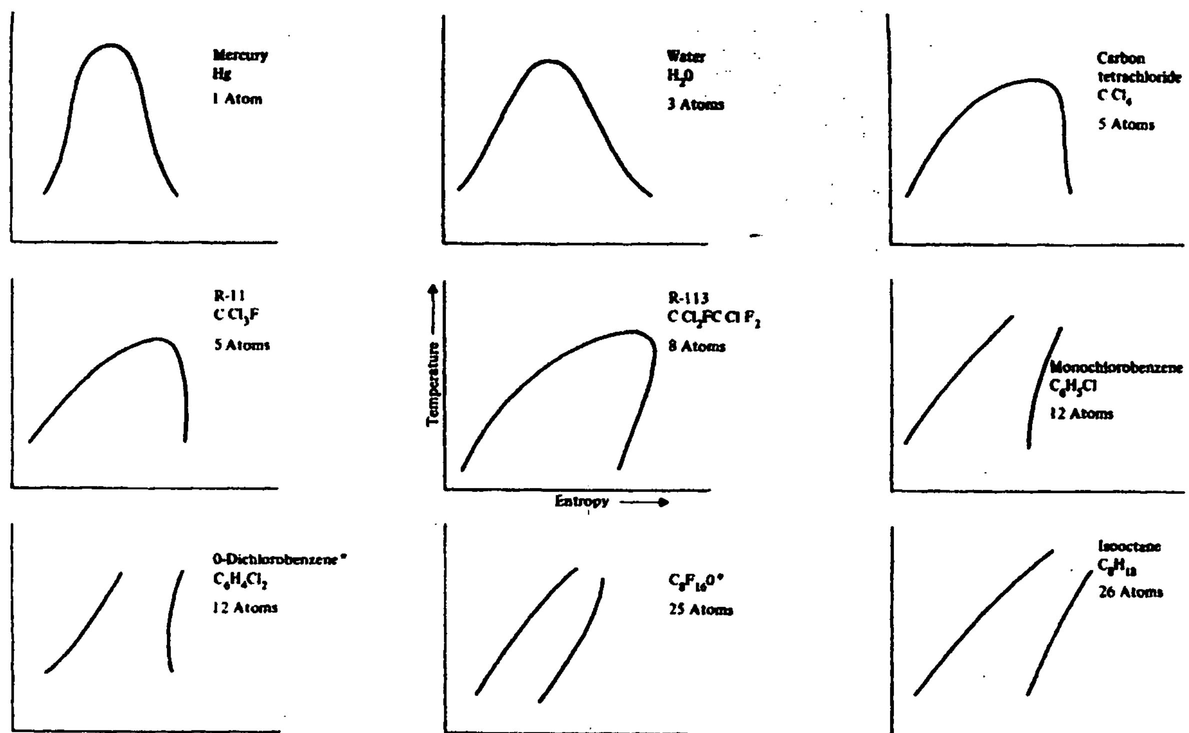
From the preceding discussions, it is clear that, for initial steam pressures over about 1200 psi, a reheat cycle is necessary to avoid unreasonably wet conditions during the expansion process, and for large power plants, regeneration is necessary for economy. **Figure 1.19** shows the vapor cycle for a very large power plant with a high-pressure turbine, reheat, an intermediate-pressure turbine, a low-pressure turbine with a separate shaft, and a total of seven points of steam extraction. All feed water heaters are of the closed type except for the deaerating heater. An **evaporator**, not previously mentioned, is used to vaporize **make-up** water that must replace leakage. The high-pressure and intermediate-pressure turbines are both balanced-flow types with the steam entering at the midpoint and expanding axially in both directions, and the low pressure unit is made up of three balanced-flow turbines on a common shaft, all discharging to the condenser. These split-flow turbines not only balance end thrust forces, but also reduce the extremely large radius necessary in later stages to accommodate the tremendous increase in specific volume as exhaust pressure is approached. Note that in this particular plant, the boiler feed pumps, which require a considerable amount of power, are driven by the output of a generator that is electrically independent of the main power generators. The whole diagram is highly schematic.

1.2.7 Alternative Working Fluids

The thermodynamic properties of water put limitations on the efficiency of a steam cycle even with the complexities of reheat and regeneration. For relatively small power plants, these complexities are not warranted, and at the same time, the cost of other fluids might not be prohibitive.

The greatest disadvantages of water as a working fluid are its high pressure and relatively low temperature at the critical point, the negative slope of the saturated vapor line on *T-s* coordinates, and its low molecular weight. Some other substances do have a vertical or positively sloped saturated vapor line. The slope is governed primarily by the number of atoms in the molecule [A.40], though that is not a completely reliable criterion.

The shapes of the saturation lines for several substances are shown on *T-s* coordinates in **Fig. 1.20**. Not all these are practical working fluids over wide ranges of temperature. For instance, the saturation pressure of mercury (Hg) becomes



* Dowtherm E. Dow Chemical Co.

* FC-75, 3M Co.

FIG. 1.20 Relative shapes of saturated liquid-vapor dome for various fluids on temperature-entropy coordinates (scales different).

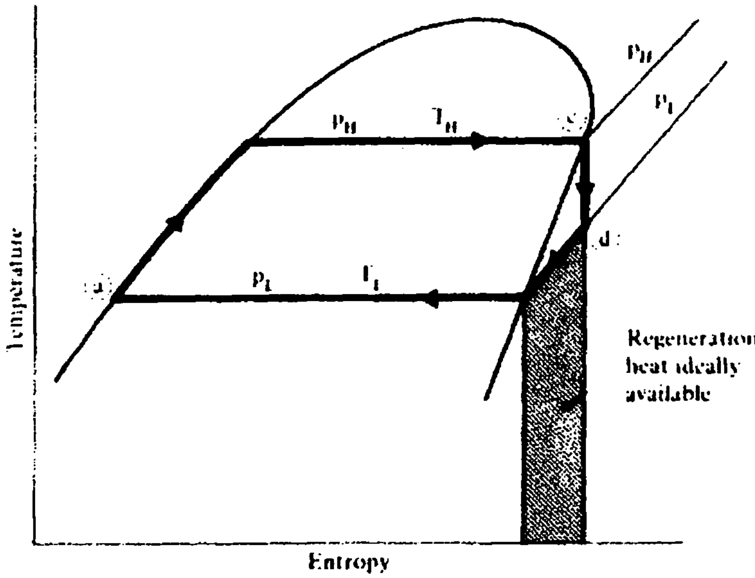


FIG. 1.21 The possibility of regeneration in a simple Rankine cycle if the saturated vapor line has a negative slope.

extremely small, and the specific volume becomes extremely large at normal ambient temperatures. Carbon tetrachloride (CCl_4) will decompose even below 500 F, a moderate temperature for reasonable cycle efficiency. Similarly, the halogenated hydrocarbons such as R-11 and R-113, developed particularly for refrigeration cycles (see Chapter 4), are unstable at the temperatures usually desired for power cycles, except that they may be quite satisfactory for relatively low temperature, waste heat recovery [A.22] and [A.28].

A nearly vertical saturated vapor line would mean that superheating above the saturation temperature at which the fluid is evaporated would not be necessary to avoid the wet vapor region at the end of isentropic expansion. While a positively sloped saturation line would guarantee dry vapor throughout the expansion process, **Fig. 1.21** shows that an increased heat rejection is unavoidable for the simple Rankine cycle. However, the temperature at the end of expansion (T_d) is higher than the temperature of condensation (T_L), so that some regeneration is possible without extraction if the condensate exchanges heat with the superheated exhaust vapor. Such regeneration is sometimes called "feed heating."

High **molecular weight** of the working fluid is desirable primarily to reduce the required blade speed of a turbine. It is possible to show that the nozzle velocity for a given temperature drop in one stage is approximately inversely proportional to the square root of the molecular weight of the fluid. The optimum blade speed is about one-half the nozzle velocity. Where a steam turbine usually requires several stages to keep the enthalpy drop per stage low, and thus keep the blade speed within the bounds of reasonable centrifugal force, a turbine using a high molecular-weight fluid might need only one stage. Although nozzle velocities

are lower for high molecular-weight fluids, the pounds per minute circulated must be greater for a given output because enthalpy drop per pound is approximately inversely proportional to the molecular weight.

The search for alternative working fluids has been going on for a long time. In a book published in 1912 [B.5], W. D. Ennis discussed nine substances besides water that had been suggested and tried by that time. Mercury was not then considered. Only water had had wide commercial success. Since then, many factors have changed. First, much more is known of the thermodynamic properties of most natural substances, and many synthetic compounds have been extensively studied. Second, vastly improved technology has made sealed systems more reliable. Third, the thermodynamics and fluid mechanics of turbines are better understood so that they can be designed for particular fluids and conditions. Fourth, the conventional range of temperatures for a stationary steam power plant will not always apply to unusual situations such as utilization of solar energy, waste heat recovery, and space flight, and unforeseen requirements of the future. Finally, in many systems, particularly small ones, the first cost of working fluid and auxiliaries may be much less important than either cycle efficiency or specific output (kilowatts per pound or per cubic foot of the power plant).

1.2.8 Binary Vapor Cycles

The high critical pressure of water and the value of its critical temperature, which is below the permissible temperature limit for boilers, are undesirable characteristics on the high side of the cycle; its very low vapor pressure at usual condensation temperature is a disadvantage on the low side. No single fluid spans the maximum possible range without some undesirable features. For this reason, cycles have been proposed and some have been built that utilize more than one fluid, each over its most satisfactory range. A **binary** vapor power cycle is one that employs two different working fluids. This is a special case of the thermally interdependent systems described in Section 1.4.2. It is similar to the binary vapor refrigeration cycles described in Chapter 4.

The earliest proposals for binary vapor cycles, over 100 years ago [B.4], were for water on the high side and a more volatile fluid (lower atmospheric boiling point) such as ether on the low side. The maximum temperatures and pressures then possible were not high for the properties of water, but the maintenance of a high condenser vacuum remained a problem for some time. The water, condensing at a temperature over 200 F, vaporized the second fluid that could then be condensed at ambient temperature after expansion to a positive gauge pressure. The development in this century of highly effective steam jet air ejectors, described previously, has made this unnecessary.

The one working fluid that has been used in a binary system with water in a few large power plants in this country is mercury. Its critical temperature, about 1649 F at 2646 psia, is above permissible temperatures to date so that superheating is not required, and its very steep liquid saturation line (low specific heat of the liquid) makes regeneration unnecessary. **Figure 1.22** presents a schematic layout for